

Synopsis

Shape memory alloys (SMAs) exhibit unique combination of structural and functional properties and hence have a variety of current and potential applications. The mechanical behaviour of SMAs, in particular the influence of processing on the microstructure, which in turn influences the performance of the alloy, mechanical properties at the nano-scale, and under cyclic loading conditions, are of great current interest. In this thesis, specific issues within each of these broad areas are examined with a view to suggest further optimize/characterize SMAs. They are the following: (a) For thermo-mechanical secondary processing of SMAs, can we identify the optimum combination of temperature- strain rate window that yields a desirable microstructure? (b) How can indentation be used to obtain information about functional properties of shape memory alloys so as to complement traditional methods? (c) How can the information obtained from indentation be utilized for the identification of the alloy composition that yields a high temperature SMA through the combinatorial diffusion couple approach?

Towards achieving the first objective, we study the hot deformation behavior of a cast NiTi alloy with a view of controlling the final microstructure. The “processing maps” approach is used to identify the optimum combination of temperature and strain rate for the thermomechanical processing of a SMA system commonly used in actuators applications (NiTiCu). Uniaxial compressions experiments are conducted in the temperature range of 800- 1050 °C and at strain rate range of 10^{-3} and 10^2 s^{-1} . 2-D power dissipation efficiency and instability maps are generated and various deformation mechanisms, which operate in different temperature–strain rate regimes, are identified with the aid of these maps. Complementary microstructural analysis of specimens (post deformation) is performed with the help of electron backscattered diffraction (EBSD) analysis to arrive at a processing route which produces stress free grains. A safe window suitable for industrial processing of this alloy which leads to grain refinement and strain-free grains (as calculated by various methods of misorientation analysis representation) is suggested. Regions of the instability (characterized by the same analysis) result in strained microstructure, which in turn can affect the performance of the SMA in a detrimental manner.

Next, to extract useful information from indentation responses, microindentation experiments at a range of temperatures (as the shape memory transformation is in progress) are conducted underneath the Vickers indenter. SME was observed to cause a change in the calculated recovery ratios at temperatures above A_s . Spherical indentation of austenite and martensite show different characteristics in elastic and elasto- plastic regimes but are similar in the plastic regime. NanoECR experiments are also conducted under a sphericoconical indenter at room temperature, where the resistance measured is observed to increase during the unloading of room temperature austenite SMA. This is a signature of the reverse transformation back to austenite during the withdrawal of the indenter.

Lastly, recovery ratios are monitored in the case of a NiTiPd diffusion couple before and after heat treatment at different temperature intervals using non- contact optical profilometry. The recovery ratio approach is successfully used to determine the useful temperature and %Pd range for a potential NiTiPd high temperature SMA. The method makes high throughput identification of high temperature shape memory alloys possible due to promising alloy compositions being identified at an early stage.